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ON THE INTERMEDIATE HOSTS OF THE LUNG DISTOME, *P. WESTERMANI* KERBERT

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Japan is famous for being considerably infested with lung distome. It is about thirty-four years since the human lung distome was discovered by Kiyono, Yamagata, Nakahama, and Suga in Okayama prefecture, near the center of the country. During these years though numerous reports on symptoms of patients and on diagnosis and many pathological notes have been published by investigators from various districts of the country, the result of the developmental investigations has not yet been achieved, nothing being known of a life history of the parasite. Fortunately, however, light has been thrown upon the subject by the recent discovery of an intermediate, probably the second, host of this worm by Koan Nakagawa, director of the Shinchiku Hospital, Formosa, who has been earnestly investigating this parasite in Formosa for several years.

I have also studied experimentally the life-history of this worm, and found certain species of fresh water crabs as intermediate hosts. I shall here communicate the results obtained from my experiments.

INTERMEDIATE HOST

In Formosa Nakagawa found the encysted larvae in two fresh water crabs and experimentally proved that they grew up to the lung distomes. The two crabs were identified by A. Terao as follows: *Potamon* (*Geothelphusa*) *obtusipes* (Stimpson), *P.* (*Ge.*) *dehaanii* (White).

Nakagawa added that a fresh-water crab *Eriocheir japonicus* (De Haan) will also probably prove to be the intermediate host.

I have experimentally proved that the encysted larvae of this worm are found in three species of fresh-water crabs from various districts of Japan proper. They are identified as follows: 1. *Patamon dehaanii* (White); 2. *Sesarma dehaani* (Milne Edwards); 3. *Eriocheir japonicus* (De Haan).

These species can be found in any part of Japan. *P. dehaanii* is small in size and light reddish brown or purple in color. It is a common crab in the shallow water of a mountain stream. This crab is edible and used for food commonly in some districts and rarely in other parts of this county. It can be eaten raw or cooked. *E. japan-*

icus is large in size and dark brown or black in color, very common in any brook and river of Japan, including Formosa and Corea. Large hairy forceps are characteristic of this species. It also is edible and commonly used for food in all districts, though generally eaten cooked being roasted, boiled, or fried. *S. dehaani* is of median size, the same in color as *E. japonicus,* having light reddish purple forceps. It lives generally in the lower parts of a river in various parts of our country. This species is not used for food.

Distribution of Encysted Larvae in Body of Intermediate Hosts.—The encysted larvae occur generally in the liver, muscles, and gills of the host. The distribution of the encysted larvae varies but slightly according to the species of the host, so far as I have examined. In *P. dehaanii* and *P. obtusipes,* they are found frequently in the liver, and rarely in muscles and gills; in *E. japonicus* chiefly in gills, muscles, and hypodermis, and rarely in the liver; and in *S. dehaani* mainly in the liver and very rarely in the gills. In the liver the encysted larvae are attached loosely to the lobes of the organ so that they may be easily detached. In the gills they adhere between the lamellae in the case of *P. dehaanii,* but are found only in the blood vessel running through the median line of the upper surface of the gill in the case of *japonicus.* In the latter species they occur not only in the muscles of the trunk, but in muscle and hypodermis of all appendages. The encysted larvae in the muscles and hypodermis or in the blood vessels are easily movable.

Frequency of Occurrence and Number of Encysted Larvae in Host.—It is reported by Nakagawa that about 100 per cent. of *P. obtusipes* are infected with the encysted larvae at Shinchiku, the most famous district for the lung distome in Formosa. Ryo Ando reported that about 40 to 70 per cent. of *P. dehaanii* of Gifu prefecture are infected with the larvae. According to my own examination *E. japonicus* of Tokushima and Okayama prefectures is infected to the extent of about 70 to 85 per cent., and *S. dehaani* of Osaka prefecture to about 20 to 80 per cent. The number of the cysts in one crab varies considerably according to species of the host, and even in the same species it varies according to locality and other conditions. In my own examinations I found some *E. japonicus* infected with several hundreds of the encysted larvae while others were infected only with a few in spite of the locality being the same. *S. dehaani* was generally infected with 2 to 30 cysts of the larvae. In *P. dehaanii* from Okayama and Nigigsta prefectures I found only a few cysts while Ando is reported to have obtained several hundreds of cysts in the same species from Gifu prefecture.

I give here tables showing the percentages of the infected crabs and the numbers of the cysts in the hosts examined by myself.

TABLE 1.—*S. DEHAANI* FROM HIEJIMA, OSAKA PREFECTURE

Date	Number of Crabs Examined	Number of Crabs Infected with Cysts	Percentage of Infected Crabs	Maximum of Cysts in One Crab	Minimum of Cysts in One Crab	Total Number of Cysts in Crabs Infected	Average Number of Cysts in One Crab	Number
10/VI	19	4	21.05%	3	1	7	1.43	1
11/VI	8	2	25.00%	2	2	4	2.00	2
12/VI	3	1	33.33%	2	2	2	2.00	3
14/VI	20	2	10.00%	2	1	3	1.50	4
15/VI	12	2	16.66%	3	1	4	2.00	5
16/VI	12	1	8.33%	1	1	1	1.00	6
17/VI	21	5	23.80%	2	1	6	1.20	7
18/VI	8	3	37.50%	4	1	7	2.33	8
22/VI	24	2	8.33%	2	1	3	1.50	9
28/VI	9	2	22.22%	3	2	5	2.50	10
10/VII	10	2	20.00%	8	2	10	5.00	11
11/VII	9	2	22.22%	7	3	10	5.00	12
12/VII	1	1	100.00%	1	1	1	1.00	13
13/VII	11	3	27.27%	3	1	6	2.00	14
14/VII	9	4	44.44%	4	1	10	2.50	15
15/VII	16	2	12.50%	2	1	3	1.50	16
16/VII	8	2	25.00%	3	2	5	2.50	17
	200	40	20.00%	8	1	87	2.17	17

TABLE 2.—*S. DEHAANI* FROM EBIE, OZAKA PREFECTURE

Date	Number of Crabs Examined	Number of Crabs Infected with Cysts	Percentage of Infected Crabs	Maximum of Cysts in One Crab	Minimum of Cysts in One Crab	Total Number of Cysts in Crabs Infected	Average Number of Cysts in One Crab	Number
28/VIII	5	4	80.0%	29	9	89	22.5	1
30/VIII	2	2	100.0%	26	26	52	26.0	2
1/IX	6	5	83.3%	30	15	107	21.4	3
2/IX	5	5	100.0%	22	1	49	9.8	4
	18	16	88.8%	30	1	297	18.5	4

TABLE 3.—*E. JAPONICUS* FROM IKUINA, TOKUSHIMA PREFECTURE

Date	Number of Crabs Examined	Number of Crabs Infected with Cysts	Percentage of Infected Crabs	Maximum of Cysts in One Crab	Minimum of Cysts in One Crab	Total Number of Cysts in Crabs Infected	Average Number of Cysts in One Crab	Number
23/VII	10	9	90 %	19	3	96	10.66	1
25/VII	4	4	100 %	26	1	56	14.00	2
26/VII	7	7	100 %	14	1	29	4.14	3
27/VII	15	13	86.6%	12	1	61	4.69	4
28/VII	1	1	100 %	86	86	86	86.00	5
2/VIII	10	3	33.3%	77	7	161	59.66	6
3/VIII	15	7	46.6%	40	1	70	10.00	7
3/VIII	5	3	60.0%	..	..	..		8
6/VIII	8	6	75 %	48	2	85	14.16	9
7/VIII	2	1	50 %	343	343	343	343.00	10
	77	54	70.1%	343	1	987	19.35	10

TABLE 4.—DISTRIBUTION OF CYSTS IN THE BODY OF NO. 10 IN TABLE 3

Gills on both sides	81
Body muscles on left side	99
Body muscles on right side	109
Forceps on right side	19
Third leg on right side	12
Third leg on left side	23

TABLE 5.—DISTRIBUTION OF CYSTS IN THE LEGS OF THE CRAB IN THE PRECEDING TABLE

	Ischiopodite Meropodite	Carpop-odite	Propo-dite	Dactylop-odite	Total
Right forceps	4	12	3	0	19
Right third leg	7	3	2	0	12
Left third leg	13	6	4	0	23
Total	24	21	9	0	54

TABLE 6.—NINE CYSTS IN GILLS, FIFTY-FIVE IN MUSCLES AND HYPODERMIS

	First Legs (Forceps)		Second Legs		Third Legs		Fourth Legs		Fifth Legs	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Muscles attached	1	2	2	1	6	4	0	2	1	1
Basipodite	1	0	2	1	0	1	0	1	0	0
Ischiopodite	1	3	0	2	0	2	1	0	0	2
Meropodite	4	3	0	0	2	0	0	2	1	1
Carpopodite	0	1	0	0	0	1	2	1	0	0
Propodite	0	0	0	0	0	0	0	0	0	0
Dactylopodite	0	0	0	0	0	0	0	0	0	0
Total	7	9	4	4	8	8	3	6	2	4

TABLE 7.—DISTRIBUTION OF CYSTS IN *E. JAPONICUS* FROM TOMIOKA, TOKUSHIMA PREFECTURE

Number	Total Number of Cysts	Cysts in Gills	Cysts in Muscles, etc.	Number	Total Number of Cysts	Cysts in Gills	Cysts in Muscles, etc.
1	7	7	...	16	106	106	...
2	5	5	...	17	...	...	...
3	5	5	...	18	...	...	...
4	98	31	64*	19	...	...	...
5	193	69	124	20	21	21	...
6	159	67	92	21	11	11	...
7	40	8	32	22	36	36	...
8	2	2	..	23	48	48	...
9	161	40	121	24	16	16	...
10	90	20	70	25	22	22	...
11	3	3	..	26	..	..	...
12	11	11	..	27	35	35	...
13	76	24	52	28	12	12	...
14	51	33	18	29	53	53	...
15	17	17	..	30	390	133	257

* Three in liver.

TABLE 8.—FROM THE ABOVE TABLE

Number of crabs examined	30
Number of crabs infected with cysts	26
Percentage of infected crabs	86.6%
Total number of cysts	1,668
Average number of cysts in one crab	64.1

TABLE 9.—DISTRIBUTION OF CYSTS IN THE MUSCLES AND THE HYPODERMIS OF ONE *E. JAPONICUS* HAVING 390 CYSTS IN ALL (NO. 30 OF TABLE 7)

	First Leg (Forceps)	Second Leg	Third Leg	Fourth Leg	Fifth Leg	Total
Body muscles attached to	49	28	28	9	12	126
Ischiopodite	..	4	0	2	0	6
Meropodite	10	11	16	16	22	75
Carpopodite	10	3	9	6	0	28
Propodite	9	2	6	3	2	22
Dactylopodite	0	0	0	0	0	0
Total	78	48	59	36	36	257

Morphology of the Encysted Larvae.—The encysted larvae found in the above named crabs are almost spherical or rarely elliptical in shape, measuring from 0.25 to 0.55 mm. in diameter. The fully grown cysts vary between 0.30 and 0.55 mm. The wall of the cyst is a transparent chitinous membrane of tolerable thickness. In the fully developed larva in a cyst one may easily and distinctly recognize the organs, for example, both oral and ventral suckers, and alimentary tract including pharynx, esophagus, intestinal coeca, and excretory vesicle. The oral and ventral suckers are of nearly equal size, the former is distinctly visible when the worm is moving and the latter becomes somewhat indistinct on account of being obstructed by an extension of the excretory vesicle. The pharynx is small, the esophagus short and the intestinal coeca run posteriad in a strongly winding course along both sides of body, ending blindly at or near the posterior end. The excretory vesicle occupies nearly all the space between the intestinal coeca.

The parenchymous tissue of the body is tinged with light red pigment so that a cyst containing a larva is easily recognizable even in liver or in muscle. This pigmentation is very convenient in searching for the cyst. The young worm just out of a cyst is generally elongated oval in shape. Under a slight pressure one may more clearly observe all the internal organs, the minute spines with which the body surface is provided and the excretory vesicle contracted in discharging its contents.

Animal Experiments with Encysted Larvae.—In the feeding experments I have used young cats and dogs. These animals were all brought from uninfested districts and were carefully examined that none of them was infected with lung distomes. Some of them have already died or been killed and used for study of the development of the young worms in these hosts, but the others are yet at the present under experimentation. I will here describe the results of some of my experiments.

(*A*) Young cat. The animal was fed with 20 cysts on July 26, 80 on the 28th, and 130 on August 2. These cysts were all taken from the gills of *E. japonicus* collected from Tokushima prefecture. The cat died August 10, having passed 16, 14 and 9 days after the first, second and third feedings, respectively. Before her death she was extremely anemic and atrophied. In dissection the next day, numerous cestode larvae were found in the body wall as well as in the body cavities, abdominal and pleural. Some portions of the body wall occupied by the worms had suppurated. It was easy to believe that the anemic and atrophic symptoms and consequently the death of the cat were caused by the presence of these larval cestodes.

In the abdominal cavity I found 18 young worms floating in serous fluid and adhering to the omentum, mesentery, and inner surface of the abdominal body wall, and in the pleural cavity 16 worms in serous fluid and on the pleural membrane. These young distomes in the body cavity were all nearly equal in size, measuring from 1 to 2 mm. in length in compressed specimens. The lungs were not yet occupied by the worms.

(*B*) Young cat. Fed with 80 cysts August 7 and killed on 17th of the same month, 11 days after feeding. All the cysts were collected from the same locality given in the preceding example. I found 5 young worms in the abdominal cavity and 6 in the pleural cavity. These worms measure about 1 mm. in length and 0.5 mm. in breadth. (Figure 6.)

(*C*) Young dog. Fed with 33 cysts August 14, 46 on 17th, 90 on 28th, 50 on 30th, and 32 on September 1. The cysts of the first and the second feedings were obtained from *E. japonicus* of Tokushima prefecture and all the remaining cysts were taken from *S. dehaani* of Ebie, a suburb of Osaka. The dog died September 29, having passed 46, 43, 32, 30, and 29 days after each corresponding feeding. Some inflammations were observed here and there in the inner surface of the intestinal wall. This seemed probably to have been caused by the action of the young worms of the lung distomes. I found also a great number of *Dipylidium caninum* and a few *Ankylostomum caninum* in the small intestine. Omentum and the mesentery were slightly congested here and there. There were numbers of perforations on the inner surface of the abdominal body wall. Around the perforations more or less hemorrhage was observed between the muscular layers of the abdominal wall. These perforations were evidently produced by the young worms which were found everywhere in the serous fluid or on the surface of various organs in the abdominal cavity where I had obtained 30 young worms. A number of perforations was observable on the diaphragm through which the young worms seem to have passed from the abdominal to the pleural cavity.

In the pleural cavity 43 young worms were obtained in the serous fluid and on the surface of the various organs: lungs, heart, and pleural membrane. The size and the shape of the worms in the body cavities were extremely variable according to the state of contraction. In fixed specimens, the length varies from 1.5 to 5 mm. and the breadth from 0.5 to 2 mm. I found a good specimen which is most favorable to demonstrate that the worm in the pleural cavity enters the lungs from its surface by perforating. Numerous worms in various stages of development were observed in the lungs. The worms of large size

in the lungs were plainly observable from the outside or easily felt by touching on the surface of lungs.

(*D*) Young cat. Fed with 4 cysts June 15, 1 on 16, and 3 on 17, and was killed on August 17. It was 62 to 64 days after the feedings. All the cysts were taken from the liver of *S. dehaani.* In the dissection of this animal I found 2 young distomes, one in the pleural cavity, the other in the right lung. The dimensions of this worm were about 4 mm. long and 2 mm. broad. The worm in the lung was not yet matured.

From my observations in the above experiments, I have learned the general course which the young worms travel from the intestine to the lungs of the host. Briefly stated, it is as follows:

The encysted larvae swallowed by a host come out of their cysts in the stomach or intestine through the action of gastric or intestinal juice. The larvae coming out of the cysts are actively mobile. They pierce the wall of the intestine. They stay for some time in the abdominal cavity and wander about here and there; thence they pierce through the diaphragm to enter the pleural cavity. Here again they stay for some time and finally penetrate into the lungs from their surface.

In addition to this general course, the young distomes in the abdominal cavity may also penetrate the abdominal wall and move around in the muscular layers of the connective tissues, as stated above in Case *C*. Some worms in the pleural cavity may proceed cephalad, taking their course through the loose connective tissues along the esophagus or the blood vessels. Thus the young worm of the lung distome has evidently a wandering power by which it can pass through the muscular and connective tissues. It is obvious that the discovery of the wandering character of the young worm throws light on the accounts of cerebral and spinal paragonimiasis which are attributed to the lung distomes.

October, 1915.

EXPLANATION OF PLATE

Fig. 1.—Cyst attached to lobule of liver of *S. dehaani.* x60.

Fig. 2.—Longitudinal section of the right third leg of *E. japonicus,* showing distribution of cysts. Natural size; b, basipodite; c, carpopodite; d, dactylopodite; g, gill; h, hypodermis; i, ischiopodite; k, muscle; l, encysted larvae; p, propodite.

Fig. 3.—Cyst from the gill of *E. japonicus.* x60; i, intestinal coeca; e, excretory vesicle; o, oral sucker; v, ventral sucker.

Fig. 4.—Larva escaping from cyst. x60.

Fig. 5.—Larva coming out of cyst; slightly compressed specimen. x60.

Fig. 6.—Young worm in abdominal cavity of young cat. x60; c, excretory canal; note also intestinal coeca.

PLATE

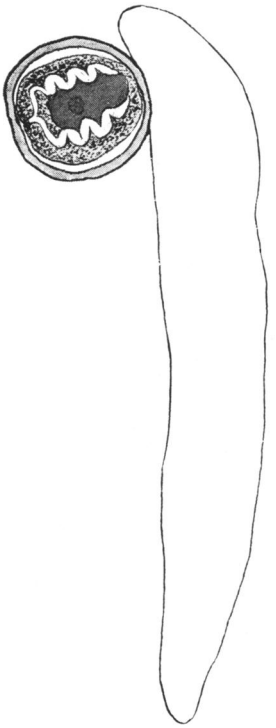


Fig. 1

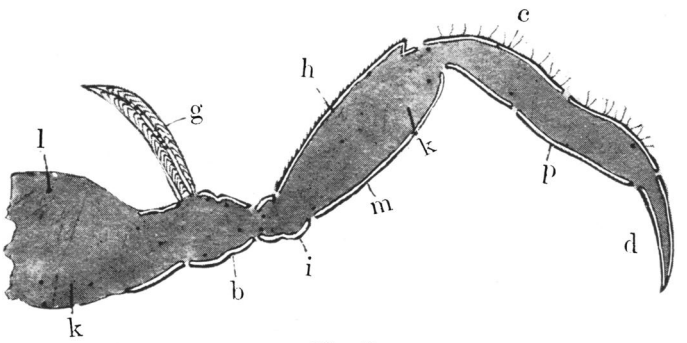


Fig. 2

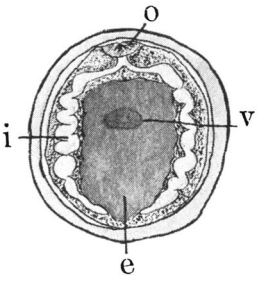


Fig. 3

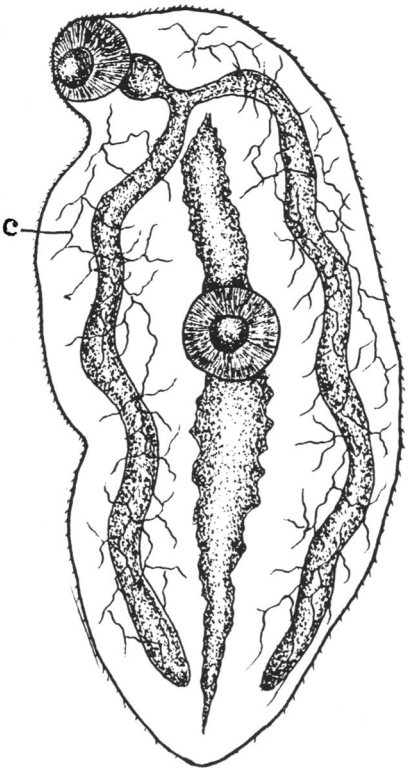


Fig. 6

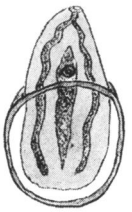


Fig. 4

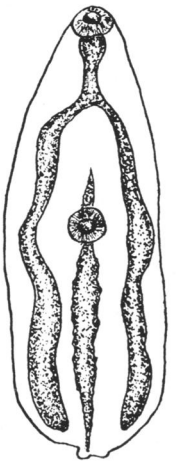


Fig. 5